PB81-217663

# Test of an Eddy Current Separator for the Recovery of Aluminum from Municipal Waste Test No. 5.01, Recovery 1, New Orleans

National Center for Resource Recovery, Inc.
Washington, DC

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Jul 81

U.S. Department of Commerce
National Technical Information Service
NTIS

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

EPA-600/2-81-117
July 1981

PB81-217663

# TEST OF AN EDDY CURRENT SEPARATOR FOR THE RECOVERY OF ALUMINUM FROM MUNICIPAL WASTE

## Test No. 5.01, Recovery 1, New Orleans

by

National Center for Resource Recovery, Inc.
Washington, D. C. 20036

6-1/2"
9-1/8"

Contract No. 68-01-4423

Project Officer

Donald A. Oberacker
Solid and Hazardous Waste Research Division
Municipal Environmental Research Laboratory
Cincinnati, Ohio 45268

MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U. S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

PRODUCT OF:
NATIONAL TECHNICAL INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

3/8"
AND ILLUS-
TRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

**TECHNICAL REPORT DATA**
*(Please read Instructions on the reverse before completing)*

| 1. REPORT NO. | 2. | 3. RECIPIENT'S ACCESSION NO. |
|---|---|---|
| EPA-600/2-81- 117 | ORD Report | PB81 217663 |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| Test of an Eddy Current Separator for the Recovery of Aluminum from Municipal Waste Test No. 5.01 Recovery 1, New Orleans | July 1981 |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT NO. |
| Staff | |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT NO. |
| National Center for Resource Recovery, Inc.<br>Washington, D.C. 20036 | 11. CONTRACT/GRANT NO. |
| | 68-01-4423 |
| 12. SPONSORING AGENCY NAME AND ADDRESS | 13. TYPE OF REPORT AND PERIOD COVERED |
| Municipal Environmental Research Laboratory - Cin.,OH<br>Office of Research and Development<br>U.S. Environmental Protection Agency<br>Cincinnati, Ohio 45268 | Final |
| | 14. SPONSORING AGENCY CODE |
| | EPA/600/14 |

15. SUPPLEMENTARY NOTES See also EPA-600/2-81-118, EPA-600/2-81- 119 and EPA-600/2-81-120.
Project Officer - Donald A. Oberacker 513/684-4417 (Carlton C. Wiles 513/684-7871)

16. ABSTRACT

This report documents three series of test runs (collectively, Test No. 5.01) of the eddy current separator that recovers principally aluminum cans from a processed portion of municipal refuse at the New Orleans Resource Recovery Project (Recovery 1). The objectives were to measure differences in efficiency and product rate which accompany an acceleration in AlMag throughput, i.e., test points of 2, 3, and 4 tph, respectively. The output streams of the eddy current separator from each test run were analyzed for aluminum-can content in three can-shape categories; the product stream was also analyzed for four categories of contamination. The efficiency of the eddy current separator in recovering each shape category of aluminum cans, as well as product purity, was determined for each test run and averaged for each test point.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| Resource Recovery<br>Refuse<br>Aluminum<br>Solid Waste<br>Material Recovery | Solid Waste<br>Resource Recovery | 13 B |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS (This Report) | 21. NO. OF PAGES |
|---|---|---|
| Release to Public | Unclassified | 29 |
| | 20. SECURITY CLASS (This page) | 22. PRICE |
| | Unclassified | |

EPA Form 2220-1 (9-73)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

## DISCLAIMER

This report has been reviewed by the Municipal Environmental Research Laboratory, U. S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U. S. Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

## FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution, and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources; for the preservation and treatment of public drinking water supplies; and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report documents a test of the eddy current separator used to recover principally aluminum cans from a processed portion of municipal refuse at the New Orleans Resource Recovery Project (Recovery 1). It is hoped that this report yields data and other information that is useful to those considering aluminum recovery from municipal refuse through mechanical processing.

Francis T. Mayo, Director
Municipal Environmental Research Laboratory

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

## ABSTRACT

This report documents three series of test runs (collectively, Test No. 5.01) of the eddy current separator that recovers principally aluminum cans from a processed portion of municipal refuse at the New Orleans Resource Recovery Project (Recovery 1). Each of the three test series consisted of three replicate test runs at a prescribed feed rate, using the same feedstock. The objectives were to measure differences in efficiency and product rate which accompany an acceleration in AlMag throughput, i.e., test points of 2, 3, and 4 tph, respectively. The output streams of the eddy current separator from each test run were analyzed for aluminum-can content in three can-shape categories; the product stream was also analyzed for four categories of contamination. After completion of the nine test runs, the non-aluminum can portion of the test feedstock was analyzed for rag-like items, moisture content, and particle size. The efficiency of the eddy current separator in recovering each shape category of aluminum cans, as well as product purity, was determined for each test run and averaged for each test point. The report details the results of the test and also describes the eddy current separator and the test and analytical procedures used.

This report was submitted in partial fulfillment of Contract No. 68-01-4423 by the National Center for Resource Recovery, Inc., under the sponsorship of the U. S. Environmental Protection Agency and covers a period from January 23, 1980, to February 1, 1980, with data analysis and reporting completed as of March 1980.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

## CONTENTS

Foreword . . . . . iii
Abstract . . . . . iv
Tables . . . . . vi
Acknowledgments. . . . . vii

1. Introduction and Summary of Test Results . . . . 1
2. Equipment Description, Sample Makeup, Test Procedure, and Sample Analysis . . . . . 6
   Equipment Description. . . . . 6
   Sample Makeup. . . . . 9
   Test Procedure . . . . . 10
   Sample Analysis. . . . . 11
3. Test Results . . . . . 13

References . . . . . 20

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

## TABLES


| Number | | Page |
|---|---|---|
| 1 | Seed Cans Used in Test Runs. . . . . | 10 |
| 2 | AlMab Efficiency . . . . . | 14 |
| 3 | AlMag Product Rate . . . . . | 15 |
| 4 | AlMag Product Contamination. . . . . | 16 |
| 5 | Characteristics of AlMag Feedstock Used in Test. . . | 17 |


9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



PAGE NUMBER
EPA-287 (Cin.)
(4-75)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
5 1/2"
9 1/8"
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

## ACKNOWLEDGMENTS

The cooperation of Recovery 1, the Waste Management, Inc., company, Mr. NOrbert J. Bolda, Recovery 1 General Manager, and of John Acevido, Supervisor, is gratefully acknowledged. The assistance of the University of New Orleans students, Michael Taylor, Michael Vesely, and Laurel Walters, who analyzed samples and assisted in this test is also acknowledged.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPY HEAD; BEGI SECTIONS HERE

## SECTION 1

## INTRODUCTION AND SUMMARY OF TEST RESULTS

There is an aluminum recovery submodule at Recovery 1 in New Orleans for the removal, cleanup, and densification of aluminum, primarily cans, found in the municipal solid waste (MSW). Installed separation equipment that impacts on the efficiency of the overall system is, in order - starting farthest upstream:

(1) a large trommel which separates unprocessed refuse into +4-3/4" and -4-3/4" fractions [1];

(2) a scalping magnet for the trommel unders;

(3) an air classifier which blows a portion of light organics away from the scalped -4-3/4" trommel unders;

(4) a two-deck flat vibrating screen which separates the air-classified heavies into three parts (+5" dia. discards, -5" dia. +2" material which is the aluminum submodule feedstock, and -2" material which is the glass submodule feedstock) [2];

(5) a second 2" flat-deck screen which processes the aluminum submodule feedstock to increase the removal of -2" material; and

(6) a scavenging magnet to remove any tramp magnetic metal.

Next comes the eddy current separator, called an AlMag, which removes the aluminum cans from the feedstock. Aluminum cans usually represent about 3 to 5%, by weight, of the AlMag feed. There is very little other aluminum or other nonferrous metal in this feed. The AlMag product is usually greater than 90%, by weight, aluminum. The remainder of the product is organics and inorganics, with a few occasional pieces of non-ferrous metal that are not aluminum cans. Downstream of the AlMag are two pneumatic separators, an air classifier, and an air knife, whose purposes, sequentially, are to (1) fly the light organics from the AlMag product [3], and (2) then blow the aluminum cans beyond the heavy organics, inorganics, and nonferrous metal that were also carried over as part of the product. The output of interest from the pneumatic separators

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



PAGE NUMBER
EPA-287 (Cin.) (4-76)

is the one with the aluminum cans. Finally, there is a shredding step which tears the cans into smaller pieces mainly to increase their density for shipping. After shredding and before shipping, -12 mesh fines are removed from the shredded aluminum product by a vibrating screen.

The AlMag is the subject of this report. This device, manufactured by Combustion Power Company, operates on the principle that an electric current is generated in each conductor (piece of metal) passing through an electromagnetic field. These "eddy currents" have a magnetic field which interacts with the applied field and produces a lateral force on the metal. This force expels the nonferrous (nonmagnetic) metal from the conveyor which carried the feed through the magnetic field. There is some carryover, or entrainment, of organics, etc., as mentioned above.

The objectives of the test reported here were to measure differences in efficiency and product rate which accompany an accelerated AlMag throughput. For the test, three operating points are described which differ in the amount of time an individual piece of aluminum is in the magnetic field and is subject to being repelled out of the burden of the feedstock, i.e., to become AlMag product. With the exception of this active time variable, an attempt was made to hold all other parameters constant, as described later in this report. The importance of the results of varying the active time is to determine whether this relatively expensive piece of equipment can be run at higher throughput levels without suffering major losses in efficiency.

If the AlMag efficiency does not fall off more rapidly than the increase in the number of recovery opportunities, i.e., the aluminum feed rate, the product rate for a given period of time will actually rise. Indeed, because of time constraints on processing waste at Recovery 1 and the cost of adding a second shift for the recovery portion of the operation, it would be preferable to accept the loss in efficiency as long as more aluminum could be recovered during the manned first shift.

The results of the test runs indicate, as would be expected, that increasing the throughput does decrease efficiency; however, for example, the decrease in efficiency (18.5%) going from 2 to 4 tph is more than compensated by the doubling of the number of aluminum can recovery opportunities. Based on the test runs which were conducted with approximately a 5%, by weight, aluminum can concentration, the product rate rose from approximately 175 pounds per hour (lb/hr) to 280 lb/hr when throughput was increased from 2 to 4 tons per hour (tph).

Three test runs were made for each throughput operating point. Two hundred pounds of feed per run were used. The throughputs chosen for the three operating points were 2, 3, and

4 tph. The last is slightly above the rated capacity of the AlMag. Efficiencies for the three runs were 80.9, 76.9, and 65.9%, respectively. The 5% aluminum can concentration was as much as twice the AlMag feed concentration currently experienced during operations at Recovery 1, even though the usual operating feed rate is close to the 4 tph figure. However, a 5% concentration could be achieved under usual operating conditions by simply increasing the efficiency of the -2" screening steps since, at present, misreported -2" material makes up more than 50%, by weight, of the AlMag feed.

Not so easily removed from the feedstock are relatively large pieces of rags, paper, and plastics which drape over, attach to, and generally impede the expulsion of the aluminum cans during the time they are subjected to the magnetic field in the AlMag. The prevalence of this flexible impeding material appears to be a principal impediment to the achievement of higher efficiencies by the AlMag.* Flat-deck screening is unlikely to be able to remove much of this flexible material with the screens currently installed. Other approaches are being investigated.

Another efficiency-decreasing influence was inconsistent feeding. If the feedstock was all relatively small, relatively dry material, and was evenly distributed on the belt of the AlMag, the burden depth for each of these test runs would have been approximately 1/2". This so-called average burden depth was one of the "constants" among all test runs. However, in actual practice, the system produces very uneven feeding. Clumps occur, at times exceeding the 4" gap between the upper and lower magnet panels, resulting in plowovers at the feed and losses from the system. In addition to the flexibles, which contribute to this clumping, the overall moisture level of the waste also tends to cause individual pieces of material to cling together rather than spread out on the belt.

For the test runs, the feedstock was fed by hand from trash containers into the chute that connects the second 2" screen to the AlMag vibrating feeder via the scavenging drum magnet. Visual observation indicated that the hand-feeding closely approximated actual operational conditions. For test purposes, the occurrence of the clumps, as well as the occurrence of the impeders (flexible organics) in any particular test run, was assumed to be random.

---

*For example, in the feedstock collected and used for the test, there were 137 individual items of rags, plastic bread wrappers, paper towels, etc. As each test run consisted of 600 linear feet of belt length, this is one impeder for every 4-1/3' of belt. For comparison, there were 256 cans.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

The non-aluminum can portion of the feedstock was material collected from AlMag "throughs," i.e., the material not recovered by the AlMag. The same material was used for each run, with representative material added to offset the losses from spillage, evaporation, and the non-aluminum material that carried over with the aluminum cans as product contamination. This product contamination was saved for laboratory analysis, as described later in this report.

The previously mentioned pneumatic product cleanup system and shredder were inactivated during the test runs so that the recovered cans could be retrieved, separated into categories, weighed, and used again in reconstituting the feedstock for the next test run. After each run, the missed cans were hand-sorted from the throughs. After categorization and weighing, these cans were also used to reconstitute the feed for the next run.

The aluminum used for seeding the AlMag feedstock consisted of cans falling into three shape categories. Shape had been demonstrated as having a rather profound impact on AlMag efficiency [4]. An analysis was made of AlMag product at Recovery 1. The cans fell into two fairly distinct shape categories and an all-other category. The first distinct category was flattened cans, probably done in the household prior to discard or by the front-end loader on the tipping floor, etc. This was about one-fifth of the cans in the AlMag product and those seeded in the test feedstock. The other distinct category was minimally deformed cans. As these were essentially whole, i.e., in their original cylindrical shape, with few dents, they are called "whole cans" in this report. They also made up about one-fifth of the cans. The remaining three-fifths were deformed in various ways, probably caused by compaction during collection and transport to Recovery 1, and perhaps by the upstream processing in the plant itself. None of these cans were flattened; none were whole. Although there was a judgment as to whether a can was deformed or only minimally deformed, i.e., whole as the term is used here, once the judgment was made, the can stayed in its designated class for all test runs. Cans in the two extreme categories (flattened and whole) were spray painted orange to aid in their identification and classification after each run.

As expected, the recovery of whole cans was significantly greater than for the other two categories. The efficiencies for the recovery of whole cans were 93.0, 88.6, and 88.3% for the three operating points, 2, 3, and 4 tph, respectively. Given that the third operating point was at twice the mass throughput of the first, it can be concluded that whole-can recovery is relatively insensitive to time in the magnetic field. Such is not the case for the other two can shape categories: the efficiency for the flattened cans was higher than for the

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-297 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA: OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

deformed, as was the relative decrease in the efficiency as throughput was increased. For the flattened cans, the efficiencies were 84.3, 81.1, and 76.7% for the three operating points, as before; while for the deformed cans, the efficiencies were 76.8, 72.6, and 65.8%. Details on the individual runs for each operating point are given in Section 3 of this report.

By and large, it appears that there would be some merit to flattening all the cans upstream of the AlMag, if this could be accomplished. One would suffer a loss in whole-can recovery, since these cans would also be flattened. However, the net gain derived from improving the recovery of those cans which were in the deformed category, if everything else stayed constant, should be about 8 lbs per hour of aluminum at the 2 tph feed rate, 12 lbs at 3 tph, and 46 lbs at 4 tph. How this can-flattening might be accomplished is being investigated.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

## SECTION 2

## EQUIPMENT DESCRIPTION, SAMPLE MAKEUP, TEST PROCEDURE, AND SAMPLE ANALYSES

### EQUIPMENT DESCRIPTION

Prior to entering the waste-receiving building, all refuse collection and transfer vehicles are weighed and recorded. In the receiving building, unprocessed MSW is deposited on the tipping floor where a front-end loader directs the waste onto either of two conveyor lines, designated Line No. 1 and Line No. 2.

From Line No. 1, the refuse is conveyed into a trommel, which is designed to remove small objects and to break open plastic and paper bags, as well as to reduce shredder wear and maintenance. The trommel is 9.75' in diameter, 45' long, with 4-3/4" circular holes in the barrel. Most of the material less than 4-3/4" passes through the trommel holes (designated trommel underflow), and is conveyed to a magnetic-drum separator for removal of ferrous, primarily tin-plated cans. The remaining material is then directed to an air classifier for further processing, or diverted to trailers for landfilling. The material larger than 4-3/4" passing through the trommel (designated trommel overflow) is conveyed to a vertical Heil shredder for size reduction to 4", nominal. Via a separate conveyor, the shredded material is transported to a second magnet, with the tailings to landfill.

From Line No. 2 in the receiving building, MSW is conveyed to a horizontal Gruendler shredder for size reduction to 6", nominal, then conveyed to the shredded material magnet. The tailings are usually directed to landfill, with the alternative of air classification and recovery of aluminum and glass.

The air classifier separates light materials, primarily paper, plastics, and textiles, from heavier materials such as glass, aluminum and other nonferrous, and some heavy organics. The air-classified light material is de-entrained and sent to the landfill. The air-classified heavy material is conveyed to the Recovery Building for further materials recovery. For purposes of this test, only trommel underflow, after magnetic

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

separation and air classification, was used to produce test sample material.

The air-classified heavy material is conveyed into a 6' x 10' double-deck vibrating flat screen, which separates the material into three output streams: +5" discards, -5" +1" aluminum submodule feedstock, and -1" glass submodule feedstock. In addition to a 5" round hole screen, the top deck consists of six parallel "grizzly" bars, 6" high and 1/4" thick, spaced 5" apart, running the length of the screen. Some paper and rags are caught on the bars and are vibrated down the screen and discharged for landfilling. The lower screen deck is punched-plate with 1" round holes. The -1" material from the screen, about 50% organics with the rest primarily glass with some stones and ceramics, is conveyed to the glass recovery submodule. Formerly, this screen had a 2" square opening bottom deck.

The -5" +1" material remains in the aluminum submodule. It consists primarily of paper, leaves, grass, plastics, textiles, wood, rubber, etc. About 2%, by weight, is aluminum cans.

The -5" +1" stream passes to a second vibrating screen, which uses grizzly bars to remove some of the long, stringy material like bread wrappers along with the -2" material. As the placement of the grizzly bars is on approximately 2" centers, some flattened cans are lost at this screening step.

The remaining -5" +2" material (some -2" material remained also) from this vibrating screen passes a rotating drum magnet. This magnet is located directly upstream of the eddy current separator's vibrating feeder and is intended to remove residual, or tramp, ferrous metal that can interfere with the operation of the AlMag. This magnetically cleaned material then drops onto the vibrating pan conveyor, which in turn feeds the AlMag.

The eddy current separator tested, an "AlMag 20" manufactured by Combustion Power Company, was designed to recover the nonmagnetic metallic material, primarily aluminum products, from a feedstock prepared as described above. The AlMag 20 is an eddy current separator that uses electromagnetic forces, created by a poly-phase current source, as a method of sorting. When a piece of conductive nonferrous (and thus nonmagnetic) metal such as aluminum passes through the magnetic field generated by the applied current, eddy currents are generated in the metal. These eddies produce their own electromagnetic field which interacts with that from the applied field. The two electromagnetic fields repel each other, and thus produce a force that levitates and repels the nonferrous metal. By arranging the electromagnetic fields perpendicular to the flow of material,

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

these forces cause nonferrous metals to move perpendicular to material flow. Thus, in the AlMag, nonferrous metals are rejected off both sides of the conveyor belt, in a direction perpendicular to the direction of belt travel. The force on a given nonmagnetic material depends on its electrical conductivity and mass density. Aluminum is preferentially separated but is not the only metal separated.

The AlMag utilizes four pairs of water-cooled electromagnets arranged about a 24"-wide conveyor. Magnets are arranged so that two pairs of magnets cover slightly more than each half of the belt. The first two pairs remove material from one half of the belt, while the other two pairs are located downstream to the first pair and remove material from the other half of the belt. The top part of each magnet pair has five poles; the bottom part has four poles. The air gap (area that the feed material flows through between the electromagnets) is variable. For the series of tests reported here, the gap was 4". Because there is occasional clumping of the feed material, a plow device is provided at the entry section to realign or deflect any oversize material to collection chutes at the sides of the separators.

The magnets utilize three-phase 480-volt power. Power consumption is about 27 kilowatts. The electrical circuits for two pairs of magnets at a time are switched off at one-minute staggered intervals for three or five seconds to prevent any tramp magnetic metal which escaped the magnetic separators from constricting the material flow. The electromagnets are water-cooled, using a water flow of about 130 gallons per hour. At this flow, the cooling water temperature rises about 70°F as it cools the magnets.

The AlMag conveyor belt speed is variable from 150 to 725 feet per minute (fpm). The belt is a slider-type configuration, 0.040" thick nylon with a stainless steel splice.

The AlMag 20 is rated to recover 75% of essentially whole aluminum cans, with less than 50% loose contamination in the product, from 3 tph of 8.5 to 11 $lb/ft^3$ feed material derived from trommel unders and processed as described above. Trommel unders result when Line No. 1 is running. For Line No. 2, which does not have a trommel, but only a shredder, the rating is for 75% recovery of shredded cans, with less than 40% loose contamination in the product, from 1.6 tph of 8.5 to 11 $lb/ft^3$ feed material.

The AlMag "product" is conveyed into an air classifier, with the "heavy" fraction dropping into an air knife. The air classifier is designed to pneumatically remove the "light"

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

organics while the air knife separates the relatively light-mass cans from the heavier organics and nonferrous metals.

This light aluminum canstock is shredded in a small hammermill to -1" round to increase bulk density to 15 - 25 $ft^3$ for shipping. Prior to loading for shipment, the shredded aluminum is screened (vibrating) to remove -12 mesh fines from the product. The resulting salable aluminum product is pneumatically conveyed to storage for shipment.

SAMPLE MAKEUP

Feedstock for the test runs was collected at the AlMag discharge (AlMag throughs) when the upstream system was operating with approximately 62-1/2 tph of MSW fed into the trommel, the nominal design condition. Residual native aluminum was removed from the collected sample material by hand sorting. Previously, a number of cans had been collected as AlMag product. These cans were divided into the three can shape categories previously mentioned: flattened, deformed, and whole. Once a particular can was placed in a category, it was marked and remained in that category for all test runs. The proportions for each category are shown in Table 1. The flattened- and whole-can categories were almost exclusively 10 oz beer cans, while this type container made up only 38% (by weight) of the deformed category. The remainder of the deformed category was composed of 12 oz soft drink and beer cans (47%), 16 oz beer cans (9%), and 8 oz beer cans (7%). The mean can weights for flattened, deformed, and whole cans were 18.0, 20.1, and 18.4 g, respectively.

There were no large differences in contamination among the three can-shape categories; the flattened cans had an estimated 7% contamination, whereas the deformed and whole cans had 9% contamination. It is unlikely that the results were affected by differences in can weight among the categories or by can contamination.

Note that the proportion, by shape, used for the test runs paralleled that found in AlMag product, not actual feed. After-the-fact calculations were done using the efficiencies for each can type found during the tests. Section 3 contains the adjusted overall efficiencies which result.

The impact of using AlMag product proportions rather than feed is that the test results for overall productivity at a particular operating point are biased slightly upward. The calculations done after the fact indicate that the feedstock should have a larger proportion of deformed cans, and this is the shape where the AlMag showed the lowest efficiency.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 1. SEED CANS USED IN TEST RUNS*

| Can Type | Number | Weight (lb) | % |
|---|---|---|---|
| Flattened | 55 | 2.19 | 20 |
| Deformed | 159 | 7.06 | 64 |
| Whole | 42 | 1.70 | 16 |
| Totals | 256 | 10.95 | 100 |

*The sample proportions were based on the proportions found in AlMag product collected with AlMag throughput of approximately 4 tph. If the 4 tph AlMag efficiencies for each can type determined from the tests are valid, it would mean that the actual composition of the feedstock was 18% (flattened), 71% (deformed), and 11% (whole). These percentages were calculated by using the efficiencies for each can type found in the 4 tph test run.

The same non-aluminum can material was used for each run. There probably was some reduction in moisture due to evaporation, and some reduction in average particle size due to handling, but neither of these changes were noted as substantial enough to affect the test results.

TEST PROCEDURE

For each run, the 189 pounds of non-aluminum can feedstock were weighed into six equal portions. The 11 pounds of aluminum seed cans were divided equally (number) among the can types into six portions and randomly distributed in each noncan feedstock portion in a trash container. The trash containers were then discharged by hand into the chute immediately preceding the scavenger magnet and AlMag vibratory feeder according to the appropriate time schedule, i.e., one trash container full every 30 seconds for the 2 tph runs, one every 20 seconds for the 3 tph runs, and one can every 15 seconds for the 4 tph runs. The total amount fed for each run was the same. Higher throughput rates were achieved by feeding faster; however, the burden on the belt remained the same, since the belt speed was also increased accordingly. Hence, ignoring the inherent variability of hand-feeding and slight changes in feedstock mentioned above:

(1) the non-aluminum portion of the feed was the same,

(2) the aluminum was the same, and

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA

(3) the burden on the AlMag conveyor belt was the same for each run.

DROPPED HEAD; BEGIN SECTIONS HERE

On the average, the burden depth was 1/2" high over about 18" of belt width. However, this is a mathematical construct, since what one sees on the belt is a clump of material here and there; an isolated can, also here and there; and a good deal of open belt space. And, since most of the cans exceed 1/2" in every dimension, one would never expect to achieve the average burden distribution in actual practice. Future tests might investigate changes in AlMag efficiency if the average burden depth were increased or decreased from the nominal depth chosen here. A deeper burden would mean an increased chance that the exit of a can would be impeded. One-half inch was chosen because, taken with the 400 fpm belt speed and the estimated bulk density of the feedstock, it produced the 4 tph figure. The 4 tph feed rate, although it is 14% over the design capacity of the AlMag, is the high-side feed rate observation for actual operating conditions experienced at the plant.

The AlMag is equipped with a plowover feature to even the feed and prevent jams. In each run, a small amount of material was pushed by the plowover into the associated chutes, including an occasional aluminum can (which then did not reach the magnetic field). These cans amounted to less than 1% of the cans in the AlMag feed for all test runs. Also, there was some aluminum lost to the scavenged ferrous chute of the ferrous magnet. This loss was 0.6% of the aluminum in the feed at 2 tph, 1.3% at 3 tph, and 1.5% at 4 tph. In all cases, the cans that were not fed into the AlMag proper were not considered in the computation of AlMag efficiency.

## SAMPLE ANALYSES

Immediately after each test run, the AlMag product was taken to the laboratory and sorted into the three can-shape categories and four contamination classifications: -4" +2" light organics (would "fly" in air classifier), -2" +1/4" light organics, heavies (would fall in air classifier), and -1/4" fines. All sorted categories were weighed. The AlMag throughs, primarily organic material which had been collected, were spread out and the "missed" seed cans retrieved, divided into the three can-shape categories, and weighed. Cross checks were made by summing weights of cans from all sources. When the can total was reconciled, the seed can portions were established, the makeup of the feedstock for the next run was begun, and the process described above was repeated.

After the runs were completed, the count of the so-called flexibles was taken, then two subsamples of the remaining non-seed can material were prepared by cone and quartering [5],

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

together they amounted to about one-eighth of the total non-can feedstock. These were screened to establish the proportions greater than 2" and less than 2" (square opening). These samples and the flexibles were then dried to determine their moisture content. The data appear in Section 3.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

## SECTION 3

## TEST RESULTS

This series of tests was designed to measure the change in AlMag efficiency when the feedstock was moved through the magnetic field at differing flow rates. The three mass flow rates used were 2, 3, and 4 tph. For a constant aluminum percentage, here 5.5% (by weight), this means that the aluminum opportunities presented to the AlMag were twice as great for any given unit of time during the 4 tph run as in the 2 tph run. Average burden on the belt was constant throughout as belt speed was increased from 200 to 300 fpm and, finally for the 4 tph run, to 400 fpm. It was expected that the aluminum can recovery percentage (AlMag efficiency) would decrease at the higher throughputs and higher belt speeds, but that the AlMag productivity (product mass flow rate) would increase. These were both found to be true.

Data on AlMag efficiency in terms of percent aluminum cans recovered are given in Table 2, and for AlMag product mass flow rate, in Table 3. Product rate is shown in lb/hr. These tables present the two important findings of the test. A third finding concerns the amount of non-aluminum can carryover, i.e., the extent to which the AlMag product contained loose contamination. These data are given in Table 4. Finally, Table 5 displays several characteristics of the AlMag feedstock.

The data shown for overall efficiency and product rate at any test point is probably biased slightly upward, i.e., greater efficiency and product rate compared to normal operating conditions. There are several reasons for this. First, the mix of can shapes in the sample material was somewhat less proportionally in deformed cans than was estimated, after the fact, to be the case for normal feedstock. This was explained in Section 2. The second reason is that there was no magnetic material in the feedstock used in the test runs. In normal operation, an occasional piece of magnetic material escapes the scavenger magnet, which necessitates the regular cycling of the AlMag magnets off and on to release the trapped magnetic material; this practice disturbs the normal operation and reduces productivity.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 2. ALMAG EFFICIENCY

(Weight Percent)

| AlMag Feed Rate | Flattened Cans | Deformed Cans | Whole Cans | Overall |
|---|---|---|---|---|
| At 2 tph | | | | |
| Run 1 | 82.1 | 74.3 | 93.0 | 78.8 |
| Run 2 | 80.0 | 81.8 | 88.5 | 82.5 |
| Run 3 | 90.8 | 74.2 | 97.7 | 81.4 |
| Composite | 84.3 | 76.8 | 93.0 | 90.9* |
| At 3 tph | | | | |
| Run 1 | 79.9 | 72.4 | 90.7 | 76.8 |
| Run 2 | 83.7 | 76.2 | 87.6 | 79.5 |
| Run 3 | 79.7 | 69.3 | 87.5 | 74.3 |
| Composite | 81.1 | 72.6 | 88.6 | 76.9* |
| At 4 tph | | | | |
| Run 1 | 76.7 | 60.4 | 90.3 | 68.5 |
| Run 2 | 79.4 | 55.8 | 90.6 | 65.9 |
| Run 3 | 74.1 | 54.2 | 84.2 | 63.2 |
| Composite | 76.7 | 56.8 | 88.3 | 65.9* |

*The adjusted efficiencies recomputed as described in the note to Table 1 are, in descending order: 80.0, 75.9, and 63.9%.

BEGIN LAST LINE OF TEXT HERE
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



PAGE NUMBER
EPA-257 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

TABLE 3. ALMAG PRODUCT RATE*

(Lb/Hr)

| AlMag Feed Rate | Flattened Cans | Deformed Cans | Whole Cans | Overall |
|---|---|---|---|---|
| At 2 tph | | | | |
| Run 1 | 36 | 103 | 32 | 171 |
| Run 2 | 36 | 114 | 31 | 181 |
| Run 3 | 40 | 100 | 33 | 174 |
| Composite | 37 | 106 | 32 | 175 |
| At 3 tph | | | | |
| Run 1 | 52 | 148 | 46 | 247 |
| Run 2 | 55 | 154 | 44 | 253 |
| Run 3 | 52 | 139 | 43 | 233 |
| Composite | 53 | 147 | 44 | 244 |
| At 4 tph | | | | |
| Run 1 | 69 | 162 | 60 | 291 |
| Run 2 | 67 | 153 | 61 | 281 |
| Run 3 | 64 | 145 | 59 | 267 |
| Composite | 67 | 153 | 60 | 280 |

*Computed from actual recovered can weights and time fed.

BEGIN LAST LINE OF TEXT HERE
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS



EPA-287 (Cin.)
(4-78)

TABLE 4. ALMAG PRODUCT CONTAMINATION
(Measured on As-Recovered Weight Basis)

| AlMag Feed Rate | Loose Contamination (lb/hr) 4" x 2" Lights | 2" x 1/4" Lights | -1/4" | Heavies | Total | All | Percent Lights and Fines |
|---|---|---|---|---|---|---|---|
| At 2 tph | | | | | | | |
| Run 1 | 1.7 | 1.3 | 0.8 | 7.0 | 10.8 | 5.9 | 2.1 |
| Run 2 | 2.5 | 1.0 | 0.5 | 7.6 | 11.7 | 6.1 | 2.1 |
| Run 3 | -0- | 1.7 | 0.5 | 1.7 | 3.9 | 2.2 | 1.2 |
| Composite | 1.4 | 1.3 | 0.6 | 5.4 | 8.8 | 4.8 | 1.8 |
| At 3 tph | | | | | | | |
| Run 1 | 0.2 | 2.5 | 0.8 | 4.3 | 3.8 | 3.1 | 1.4 |
| Run 2 | 1.1 | 2.2 | 0.7 | 3.9 | 7.9 | 3.0 | 1.5 |
| Run 3 | 0.4 | 2.4 | 0.6 | 8.1 | 11.6 | 4.7 | 1.4 |
| Composite | 0.6 | 2.4 | 0.7 | 5.5 | 9.1 | 3.6 | 1.4 |
| At 4 tph | | | | | | | |
| Run 1 | 1.7 | 1.3 | 1.3 | 50.3 | 54.6 | 15.8 | 1.2 |
| Run 2 | 6.1 | 1.7 | 0.4 | 7.1 | 15.3 | 5.2 | 2.8 |
| Run 3 | 0.3 | 2.1 | 0.5 | 7.5 | 10.4 | 3.7 | 1.0 |
| Composite | 2.7 | 1.7 | 0.8 | 21.6 | 26.8 | 8.7 | 1.7 |

TABLE 5. CHARACTERISTICS OF ALMAG FEEDSTOCK USED IN TEST

| Size | Other Non-Aluminum Component | Composition (Weight Percent, As-Tested or Wet Basis) | Percent Moisture (Wet Basis) | Composition (Weight Percent, Dry Basis) |
|---|---|---|---|---|
| +2" | Aluminum beverage cans | 5.5 | -0- | 9.3 |
| | Flexibles | 6.5* | 52.3 | 5.3 |
| | Other non-aluminum components | 20.8 | 39.0 | 21.6 |
| -2" | All non-aluminum components | 67.2 | 44.2 | 63.8 |
| | Totals | 100.0 | 41.2 | 100.0 |

*137 items were found in 200 lb of feedstock.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Under normal operation, a piece of tramp iron could be attracted by an AlMag magnet until that magnet's off period was reached. The period in which a piece of tramp iron is held by a magnet is accompanied by a reduced magnetic strength for that magnet pair (shunting) and an increased chance for jams and for pushing of contamination into the product. Since no tramp iron was present in the test feedstock, these performance-reducing conditions did not exist; however, the magnet off cycle did have an effect on efficiency: for the 2 and 3 tph test series, the magnets were off (not functioning) 6.7% of the test run duration, while for the 4 tph series, they were off 4.4% of the time. Therefore, there was a slight bias toward a higher AlMag efficiency for the 4 tph series, compared to the 2 and 3 tph series. Finally, the hand-feeding technique used in the test runs produced a somewhat more uniform feed rate than that usually observed; therefore, there were probably fewer losses to plowovers and less impedance to recovery of cans.

None of these potential biases is considered significant in terms of the test findings. Other AlMag operating conditions that would have affected the magnets' strengths, such as magnet cooling water temperature and supply voltage, did not appreciably vary among all test runs.

9 1/8"

Referring to Table 2, which presents AlMag efficiency, it can be seen that efficiency dropped as the length of time an individual can was in the magnetic field decreased. Looking at the difference between the 2 and 4 tph composite, one finds that the decrease was the greatest for the deformed cans, i.e., 26%. The composite is derived by summing the results for all three runs at a particular test point (feed rate). For the flattened cans, the decrease between the 2 and 4 tph test points was 9.0%, and for the whole cans, 5%. Unfortunately, roughly two-thirds of the can opportunities were in the deformed category; otherwise, one could conclude that, within the range tested, the AlMag was rather insensitive to feedrate. The overall decrease in efficiency between 2 and 4 tph was 18.5%.

The note in Table 2 shows the adjusted efficiencies reflecting a recalculation of the proportion of cans by various shapes, as explained in the note in Table 1. The decrease is relatively small, about 3% in the most severely affected case (4 tph feed rate).

Turning now to Table 3, one finds a significant increase in AlMag product rate as the throughput was increased. This is to be expected since, for example, when the feed rate was increased from 2 to 4 tph, there was only an 18.5% decrease in efficiency, while the opportunities for recovery were doubled. The product rate rose from 175 lb/hr to 280 lb/hr when the opportunities for recovery were doubled. This is an increase of 60% in aluminum

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

recovered in a given time interval. For the individual can-shape categories, there was an 88% increase in product rate for the whole cans, and an 81% increase for the flattened cans. The deformed-can category had a similar increase which reduced the overall increase in product rate to only 44%. Recall that for the test seed cans, this category comprised 64% (by weight) of the opportunities.

Table 4 displays loose contamination in the AlMag product. The degree of contamination was very low compared to the design limit and, at least for the lights (they would "fly" in the air classifier), appears to be virtually independent of feedrate. Except for one run, the same can be said for the "heavies" as well. For Run 1 of the 4-tph series, the heavy contamination was six times that of any other run. If this run were dropped from the test results, then the average loose contamination for all runs is about 5%. For the light contaminants, the figure is even lower, of course. By and large, light contamination accounted for about half of the total loose contamination.

Table 5 provides some information on the AlMag feedstock. The seeded aluminum can stock concentration was slightly higher than the 5% target - 5.5%, measured on an as-tested basis. The 137 items in the feedstock, mentioned in the Introduction as being impediments to recovery of aluminum cans, are here called flexibles. The flexibles were plastic bread wrappers, diapers, paper towels, etc. Note that the moisture content for this material was over 50%. The moisture level of the remainder was about 40%, compared to the total feedstock moisture of 41%.

Note also from Table 5 that 67% of the feedstock was -2" in size. This is material that would be screened out if the upstream unit processes were as effective as they should be. Steps are being taken to improve these screening steps, as well as to decrease the number of flexibles. Both steps should enhance AlMag performance for two reasons: (1) through increased screening; for example, the amount of clumping of -2" material should be reduced and therefore the AlMag should perform better; (2) through removal of the oversized flexibles, AlMag efficiency should increase, along with a probable increase in AlMag capacity. The organics and other materials that cannot be removed by screening are in the same size range as the cans (-4" +2"). However, some objects, e.g., a diaper in a plastic bag, might be removed by an air knife. The possibility for installation of such a device immediately upstream of the AlMag is being investigated.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

## REFERENCES

1. National Center for Resource Recovery, Inc., Trommel Performance at Nominal Design Conditions, Test No. 1.01, Prepared for the U. S. Environmental Protection Agency, Cincinnati, Ohio, under Contract No. 68-01-4423, March 1980, 129 pp. Also available in abbreviated form as Trommel Initial Operating Report: Recovery 1, National Center for Resource Recovery, TR-78-3, October 1978, 26 pp.

2. Bagalman, Perry M., Runyon, Kelly, Test of a Double-Deck Vibrating Screen Employed as an Aluminum and Glass Concentrator, Test No. 5.07, prepared for the U. S. Environmental Protection Agency, Cincinnati, Ohio, under Contract No. 68-01-4423, May 1980, 56 pp.

3. National Center for Resource Recovery, Inc., Performance of an Air Classifier to Remove Light Organic Contamination from Aluminum Recovered from Municipal Waste by Eddy Current Separation, Test No. 5.03, prepared for the U. S. Environmental Protection Agency, Cincinnati, Ohio, under Contract No. 68-01-4423, May 1980, 17 pp.

4. National Center for Resource Recovery, Inc., Prototype Air Knife Device for Aluminum Recovery Initial Operating Report, TR-77-3, August 1978, 24 pp.

5. American Society for Testing and Materials, "Method for Reducing Field Samples of Aggregate to Testing Size," No. C702, Philadelphia, Pennsylvania, 4 pp.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"



EPA-287 (Cin.)
(4-76)